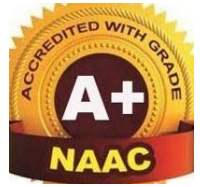




ROHINI COLLEGE OF ENGINEERING & TECHNOLOGY



DEPARTMENT OF MECHANICAL ENGINEERING

UNIT I – FUNDAMENTAL CONCEPTS IN DESIGN

1.2 MANUFACTURING CONSIDERATIONS IN MACHINE DESIGN

Manufacturing Processes

The knowledge of manufacturing processes is of great importance for a design engineer. The following are the various manufacturing processes used in Mechanical Engineering.

1. Primary shaping processes. The processes used for the preliminary shaping of the machine component are known as primary shaping processes. The common operations used for this process are casting, forging, extruding, rolling, drawing, bending, shearing, spinning, powder metal forming, squeezing, etc.

2. Machining processes. The processes used for giving final shape to the machine component, according to planned dimensions are known as machining processes. The common operations used for this process are turning, planning, shaping, drilling, boring, reaming, sawing, broaching, milling, grinding, hobbing, etc.

3. Surface finishing processes. The processes used to provide a good surface finish for the machine component are known as surface finishing processes. The common operations used for this process are polishing, buffing, honing, lapping, abrasive belt grinding, barrel tumbling, electroplating, super finishing, sheradizing, etc.

4. Joining processes. The processes used for joining machine components are known as joining processes. The common operations used for this process are welding, riveting, soldering, brazing, screw fastening, pressing, sintering, etc.

5. Processes effecting change in properties. These processes are used to impart certain specific properties to the machine components so as to make them suitable for particular operations or uses. Such processes are heat treatment, hot-working, cold-working and shot peening.

Other considerations in Machine design

1. Workshop facilities.
2. Number of machines to be manufactured
3. Cost of construction

4. Assembling

Interchangeability

The term interchangeability is normally employed for the mass production of identical items within the prescribed limits of sizes. A little consideration will show that in order to maintain the sizes of the part within a close degree of accuracy, a lot of time is required. But even then there will be small variations. If the variations are within certain limits, all parts of equivalent size will be equally fit for operating in machines and mechanisms. Therefore, certain variations are recognized and allowed in the sizes of the mating parts to give the required fitting. This facilitates to select at random from a large number of parts for an assembly and results in a considerable saving in the cost of production.

In order to control the size of finished part, with due allowance for error, for interchangeable parts is called *limit system*. It may be noted that when an assembly is made of two parts, the part which enters into the other, is known as *enveloped surface* (or *shaft* for cylindrical part) and the other in which one enters is called *enveloping surface* (or *hole* for cylindrical part). The term *shaft* refers not only to the diameter of a circular shaft, but it is also used to designate any external dimension of a part. The term *hole* refers not only to the diameter of a circular hole, but it is also used to designate any internal dimension of a part.

Important Terms used in Limit System

The following terms used in limit system (or interchangeable system) are important from the subject point of view:

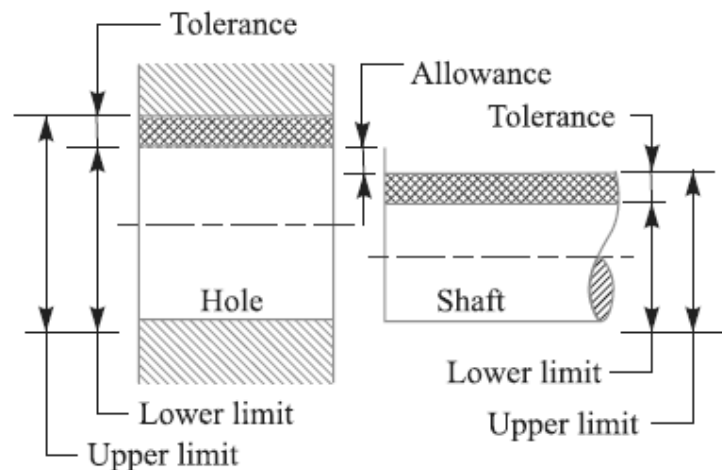


Fig. Limits of sizes.

1. **Nominal size.** It is the size of a part specified in the drawing as a matter of convenience.
2. **Basic size.** It is the size of a part to which all limits of variation (i.e. tolerances) are applied to arrive at final dimensioning of the mating parts. The nominal or basic size of a part is often the same.
3. **Actual size.** It is the actual measured dimension of the part. The difference between the basic size and the actual size should not exceed a certain limit; otherwise it will interfere with the interchangeability of the mating parts.
4. **Limits of sizes.** There are two extreme permissible sizes for a dimension of the part as shown in Fig. The largest permissible size for a dimension of the part is called **upper** or **high** or **maximum limit**, whereas the smallest size of the part is known as **lower** or **minimum limit**.
5. **Allowance.** It is the difference between the basic dimensions of the mating parts. The allowance may be **positive** or **negative**. When the shaft size is less than the hole size, then the allowance is **positive** and when the shaft size is greater than the hole size, then the allowance is **negative**.



Fig. Method of assigning Tolerances

6. **Tolerance zone.** It is the zone between the maximum and minimum limit size.

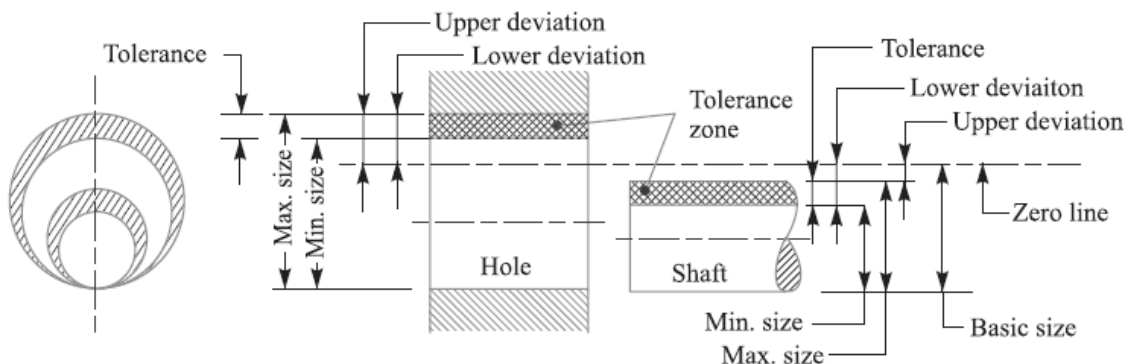


Fig. Tolerance Zone

7. **Zero line.** It is a straight line corresponding to the basic size. The deviations are measured from this line. The positive and negative deviations are shown above and below the zero line respectively.

8. Upper deviation. It is the algebraic difference between the maximum size and the basic size. The upper deviation of a hole is represented by a symbol ES (Ecart Superior) and of a shaft, it is represented by es.

9. Lower deviation. It is the algebraic difference between the minimum size and the basic size. The lower deviation of a hole is represented by a symbol EI (Ecart Inferior) and of a shaft, it is represented by ei.

10. Actual deviation. It is the algebraic difference between an actual corresponding basic size.

11. Mean deviation. It is the arithmetical mean between the upper and lower deviations.

12. Fundamental deviation. It is one of the two deviations which are conventionally chosen to define the position of the tolerance zone in relation to zero line, as shown in Fig.

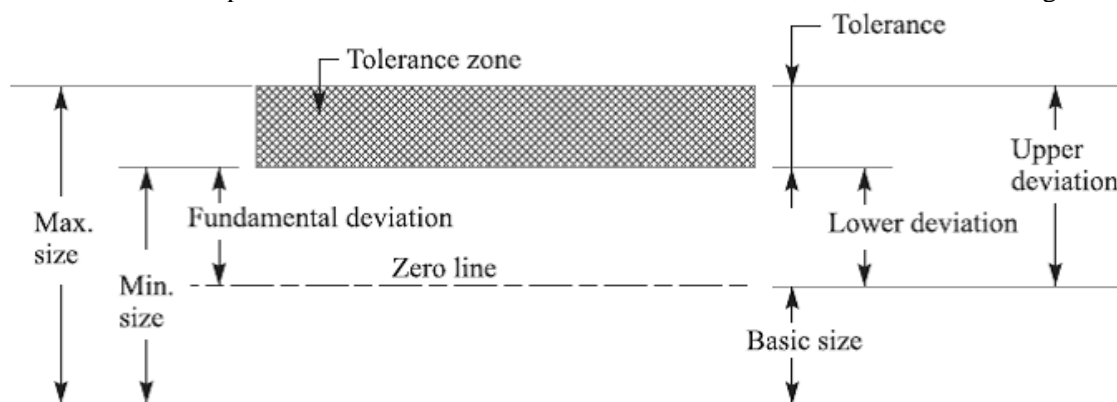


Fig. Fundamental deviation.

Fits : The degree of tightness or looseness between the two mating parts is known as a *fit* of the parts. The nature of fit is characterized by the presence and size of clearance and interference. The *clearance* is the amount by which the actual size of the shaft is less than the actual size of the mating hole in an assembly as shown in Fig. 3.5 (a). In other words, the clearance is the difference between the sizes of the hole and the shaft before assembly. The difference must be *positive*.

The *clearance* is the amount by which the actual size of the shaft is less than the actual size of the mating hole in an assembly as shown in Fig. (a). In other words, the clearance is the difference between the sizes of the hole and the shaft before assembly. The difference must be *positive*.

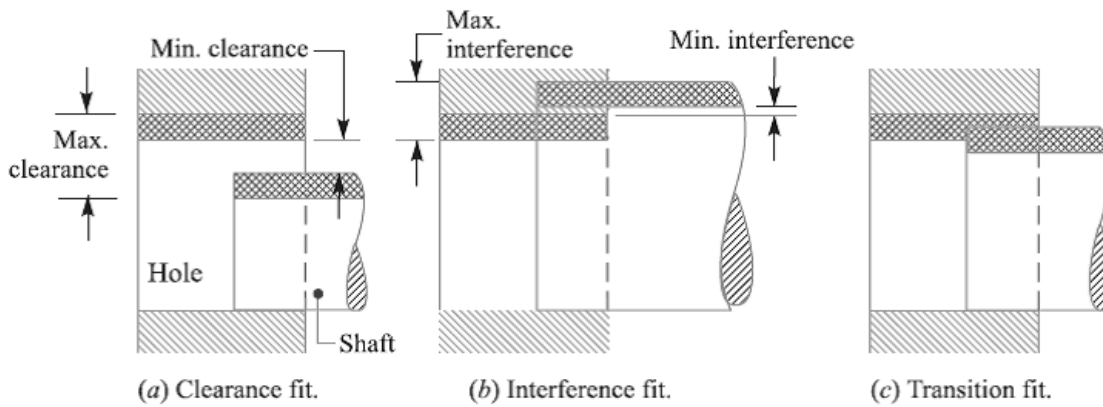


Fig. Types of fits.

The **interference** is the amount by which the actual size of a shaft is larger than the actual finished size of the mating hole in an assembly as shown in Fig. (b). In other words, the

interference is the arithmetical difference between the sizes of the hole and the shaft, before assembly. The difference must be **negative**.

Types of Fits

According to Indian standards, the fits are classified into the following three groups:

1. Clearance fit. In this type of fit, the size limits for mating parts are so selected that clearance between them always occur, as shown in Fig. (a). It may be noted that in a clearance fit, the tolerance zone of the hole is entirely above the tolerance zone of the shaft. In a clearance fit, the difference between the minimum size of the hole and the maximum size of the shaft is known as **minimum clearance** whereas the difference between the maximum size of the hole and minimum size of the shaft is called **maximum clearance** as shown in Fig. (a). The clearance fits may be slide fit, easy sliding fit, running fit, slack running fit and loose running fit.

2. Interference fit. In this type of fit, the size limits for the mating parts are so selected that interference between them always occur, as shown in Fig. (b). It may be noted that in an interference fit, the tolerance zone of the hole is entirely below the tolerance zone of the shaft. In an interference fit, the difference between the maximum size of the hole and the minimum size of the shaft is known as **minimum interference**, whereas the difference between the minimum size of the hole and the maximum size of the shaft is called **maximum interference**, as shown in Fig. (b).

The interference fits may be shrink fit, heavy drive fit and light drive fit.

3. Transition fit. In this type of fit, the size limits for the mating parts are so selected that either a clearance or interference may occur depending upon the actual size of the mating parts, as shown in Fig. (c). It may be noted that in a transition fit, the tolerance zones of hole and shaft overlap. The transition fits may be force fit, tight fit and push fit.

Basis of Limit System

The following are two bases of limit system:

1. **Hole basis system.** When the hole is kept as a constant member (*i.e.* when the lower deviation of the hole is zero) and different fits are obtained by varying the shaft size, as shown in Fig. (a), then the limit system is said to be on a hole basis.

2. **Shaft basis system.** When the shaft is kept as a constant member (*i.e.* when the upper deviation of the shaft is zero) and different fits are obtained by varying the hole size, as shown in Fig.(b), Then the limit system is said to be on a shaft basis.

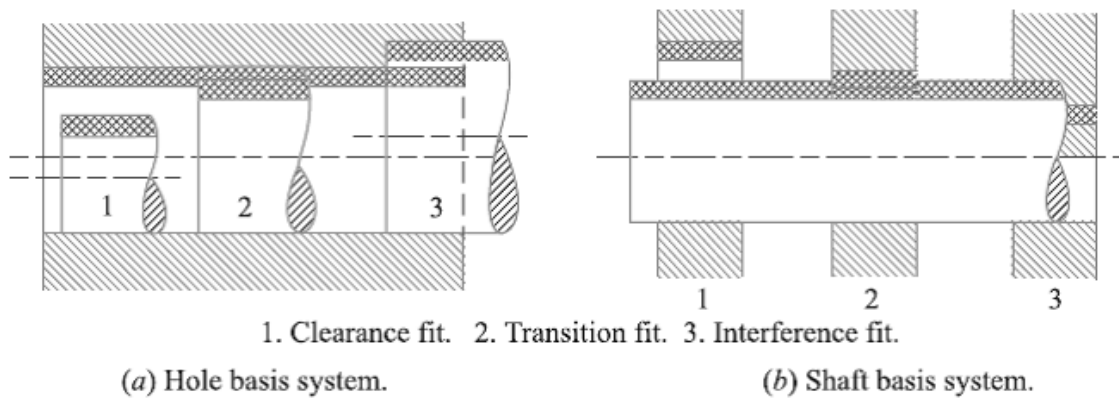


Fig. Bases of Limit System.

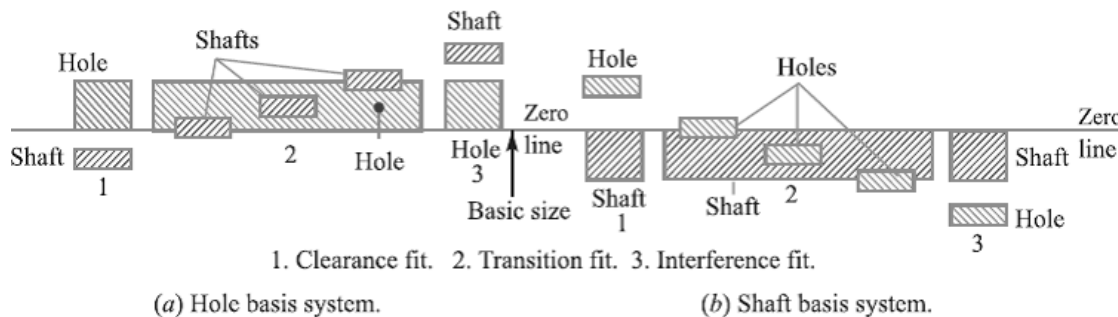


Fig. Bases of Limit System

The hole basis and shaft basis system may also be shown as in Fig. with respect to the zero line. It may be noted that from the manufacturing point of view, a hole basis system is always preferred. This is because the holes are usually produced and finished by standard tooling like drill, reamers, etc., whose size is not adjustable easily. On the other hand, the size of the shaft (which is to go into the hole) can be easily adjusted and is obtained by turning or grinding operations.

Problem-1:

The dimensions of the mating parts, according to basic hole system, are given as follows:

Hole : 25.00 mm Shaft : 24.97 mm
 25.02 mm 24.95 mm

Find the hole tolerance, shaft tolerance and allowance.

Solution. Given : Lower limit of hole = 25 mm ; Upper limit of hole = 25.02 mm ;
Upper limit of shaft = 24.97 mm ; Lower limit of shaft = 24.95 mm

Hole tolerance

We know that hole tolerance

$$\begin{aligned} &= \text{Upper limit of hole} - \text{Lower limit of hole} \\ &= 25.02 - 25 = 0.02 \text{ mm Ans.} \end{aligned}$$

Shaft tolerance

We know that shaft tolerance

$$\begin{aligned} &= \text{Upper limit of shaft} - \text{Lower limit of shaft} \\ &= 24.97 - 24.95 = 0.02 \text{ mm Ans.} \end{aligned}$$

Allowance

We know that allowance

$$\begin{aligned} &= \text{Lower limit of hole} - \text{Upper limit of shaft} \\ &= 25.00 - 24.97 = 0.03 \text{ mm Ans.} \end{aligned}$$

Problem-2:

Calculate the tolerances, fundamental deviations and limits of sizes for the shaft designated as 40 H8 / f7.

Solution. Given: Shaft designation = 40 H8 / f7

The shaft designation 40 H8 / f7 means that the basic size is 40 mm and the tolerance grade for the hole is 8 (*i.e.* IT 8) and for the shaft is 7 (*i.e.* IT 7).

Tolerances

Since 40 mm lies in the diameter steps of 30 to 50 mm, therefore the geometric mean diameter,

$$D = \sqrt{30 \times 50} = 38.73 \text{ mm}$$

We know that standard tolerance unit,

$$\begin{aligned} i &= 0.45 \sqrt[3]{D} + 0.001 D \\ &= 0.45 \sqrt[3]{38.73} + 0.001 \times 38.73 \\ &= 0.45 \times 3.38 + 0.03873 = 1.559 73 \text{ or } 1.56 \text{ microns} \\ &= 1.56 \times 0.001 = 0.001 56 \text{ mm} \quad \dots(\because 1 \text{ micron} = 0.001 \text{ mm}) \end{aligned}$$

From Table 3.2, we find that standard tolerance for the hole of grade 8 (IT 8)

$$= 25 i = 25 \times 0.001 56 = 0.039 \text{ mm Ans.}$$

and standard tolerance for the shaft of grade 7 (IT 7)

$$= 16 i = 16 \times 0.001 56 = 0.025 \text{ mm Ans.}$$

Fundamental deviation

We know that fundamental deviation (lower deviation) for hole H ,

$$EI = 0$$

From Table 3.7, we find that fundamental deviation (upper deviation) for shaft f ,

$$\begin{aligned} es &= -5.5 (D)^{0.41} \\ &= -5.5 (38.73)^{0.41} = -24.63 \text{ or } -25 \text{ microns} \\ &= -25 \times 0.001 = -0.025 \text{ mm Ans.} \end{aligned}$$

\therefore Fundamental deviation (lower deviation) for shaft f ,

$$ei = es - IT = -0.025 - 0.025 = -0.050 \text{ mm Ans.}$$

The -ve sign indicates that fundamental deviation lies below the zero line.

Limits of sizes

We know that lower limit for hole

$$= \text{Basic size} = 40 \text{ mm Ans.}$$

Upper limit for hole = Lower limit for hole + Tolerance for hole

$$= 40 + 0.039 = 40.039 \text{ mm Ans.}$$

Upper limit for shaft = Lower limit for hole or Basic size - Fundamental deviation

(upper deviation) $\dots (\because \text{Shaft } f \text{ lies below the zero line})$

$$= 40 - 0.025 = 39.975 \text{ mm Ans.}$$

and lower limit for shaft = Upper limit for shaft - Tolerance for shaft

$$= 39.975 - 0.025 = 39.95 \text{ mm Ans.}$$

Problem-3:

A journal of nominal or basic size of 75 mm runs in a bearing with close running fit. Find the limits of shaft and bearing. What is the maximum and minimum clearance?

Solution. Given: Nominal or basic size = 75 mm

From Table 3.5, we find that the close running fit is represented by $H 8/g 7$, i.e. a shaft $g 7$ should be used with $H 8$ hole.

Since 75 mm lies in the diameter steps of 50 to 80 mm, therefore the geometric mean diameter,

$$D = \sqrt{50 \times 80} = 63 \text{ mm}$$

We know that standard tolerance unit,

$$\begin{aligned} i &= 0.45 \sqrt[3]{D} + 0.001 D = 0.45 \sqrt[3]{63} + 0.001 \times 63 \\ &= 1.79 + 0.063 = 1.853 \text{ micron} \\ &= 1.853 \times 0.001 = 0.001 853 \text{ mm} \end{aligned}$$

\therefore Standard tolerance for hole ' H ' of grade 8 ($IT 8$)

$$= 25 i = 25 \times 0.001 853 = 0.046 \text{ mm}$$

and standard tolerance for shaft ' g ' of grade 7 ($IT 7$)

$$= 16 i = 16 \times 0.001 853 = 0.03 \text{ mm}$$

From Table 3.7, we find that upper deviation for shaft g ,

$$\begin{aligned} es &= -2.5 (D)^{0.34} = -2.5 (63)^{0.34} = -10 \text{ micron} \\ &= -10 \times 0.001 = -0.01 \text{ mm} \end{aligned}$$

∴ Lower deviation for shaft g ,

$$ei = es - IT = -0.01 - 0.03 = -0.04 \text{ mm}$$

We know that lower limit for hole

$$= \text{Basic size} = 75 \text{ mm}$$

Upper limit for hole = Lower limit for hole + Tolerance for hole

$$= 75 + 0.046 = 75.046 \text{ mm}$$

Upper limit for shaft = Lower limit for hole – Upper deviation for shaft

... (∵ Shaft g lies below zero line)

$$= 75 - 0.01 = 74.99 \text{ mm}$$

and lower limit for shaft = Upper limit for shaft – Tolerance for shaft

$$= 74.99 - 0.03 = 74.96 \text{ mm}$$

We know that maximum clearance

$$= \text{Upper limit for hole} - \text{Lower limit for shaft}$$

$$= 75.046 - 74.96 = 0.086 \text{ mm Ans.}$$

and minimum clearance = Lower limit for hole – Upper limit for shaft

$$= 75 - 74.99 = 0.01 \text{ mm Ans.}$$